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Carbon sources in fruit carbonate of buglossoides arvensis and consequences for ^{14}C dating

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Abstract

© 2017 by the Arizona Board of Regents on behalf of the University of Arizona. Fruit carbonate of Buglossoides arvensis (syn. Lithospermum arvense) is a valuable dating and paleoenvironmental proxy for late Quaternary deposits and cultural layers because CaCO 3 in fruit is assumed to be accumulated from photosynthetic carbon (C). However, considering the uptake of HCO 3 - by roots from soil solution, the estimated age could be too old depending on the source of HCO 3 - allocated in fruit carbonate. Until now, no studies have assessed the contributions of photosynthetic and soil C to the fruit carbonate. To evaluate this, the allocation of photo- assimilated carbon and root uptake of HCO 3 - was examined by radiocarbon (14 C) labeling and tracing. B. arvensis was grown in carbonate- free and carbonate- containing soils (sand and loess, respectively), where 14 C was provided as (1) 14 CO 2 in the atmosphere (5 times shoot pulse labeling), or (2) Na 2 14 CO 3 in soil solution (root- labeling; 5 times by injecting labeled solution into the soil) during one month of fruit development. Distinctly different patterns of 14 C distribution in plant organs after root- and shoot labeling showed the ability of B. arvensis to take up HCO 3 - from soil solution. The highest 14 C activity from root labeling was recovered in roots, followed by shoots, fruit organics, and fruit carbonate. In contrast, 14 C activity after shoot labeling was the highest in shoots, followed by fruit organics, roots and fruit carbonate. Total photo- assimilated C incorporated via shoot labeling in loess-grown plants was 1.51mg lower than in sand, reflecting the presence of dissolved carbonate (i.e. CaCO 3) in loess. Loess carbonate dissolution and root- respired CO 2 in soil solution are both sources of HCO 3 - for root uptake. Considering this dilution effect by carbonates, the total incorporated HCO 3 - comprised 0.15% of C in fruit carbonate after 10 hr of shoot labeling. However, if the incorporated HCO 3 - during 10 hr of shoot labeling is extrapolated for the whole month of fruit development (i.e. 420- hr photoperiod), fruit carbonate in loess- grown plants incorporated approximately 6.3% more HCO 3 - than in sand. Therefore, fruit carbonates from plants grown on calcareous soils may yield overestimated 14 C ages around 500 yr because of a few percentage uptake of HCO 3 - by roots. However, the age overestimation because of HCO 3 - uptake becomes insignificant in fruits older than approximately 11,000 yr due to increasing uncertainties in age determination.

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Keywords

14 C labeling, Biogenic carbonate, Buglossoides arvensis, Lithospermum arvense, Paleoenvironmental proxy, Radiocarbon dating, Reservoir effect

References

[1] Amiro BD, Ewing LL. 1992. Physiological conditions and uptake of inorganic carbon-14 by plant roots. Environmental and Experimental Botany 32: 203-11.

[2] Aylward GH. 2007. SI chemical data. Milton, Australia: John Wiley & Sons.

[3] Brix H. 1990. Uptake and photosynthetic utilization of sediment-derived carbon by Phragmites australis (Cav.) Trin. ex Steudel. Aquatic Botany 38:377-89.

[4] Cramer MD, Gao ZF, Lips SH. 1999. The influence of dissolved inorganic carbon in the rhizosphere on carbon and nitrogen metabolism in salinitytreated tomato plants. New Phytologist 142: 441-50.

[5] Cramer MD, Lips SH. 1995. Enriched rhizosphere CO concentrations can ameliorate the influence of salinity on hydroponically grown tomato plants. Plant Physiology 94:425-32.

[6] Cramer MD, Richards MB. 1999. The effect of rhizosphere dissolved inorganic carbon on gas exchange characteristics and growth rates of tomato seedlings. Journal of Experimental Botany 50:79-87.

[7] Ford CR, Wurzburger N, Hendrick RL, Teskey RO. 2007. Soil DIC uptake and fixation in Pinus taeda seedlings and its C contribution to plant tissues and ectomycorrhizal fungi. Tree Physiology 27:375-83.

[8] Gocke M, Pustovoytov K, Kuzyakov Y. 2011. Carbonate recrystallization in root-free soil and rhizosphere of Triticum aestivum and Lolium perenne estimated byC labeling. Biogeochemistry 103:209-22.

[9] Goodfriend GA. 1987. Radiocarbon age anomalies in shell carbonate of land snails from semiarid areas. Radiocarbon 29(2):159-67.

[10] Jahren AH, Amundson R, Kendall C, Wigand P. 2001. Paleoclimatic reconstruction using the correlation in δO of hackberry carbonate and environmental water, North America. Quaternary Research 56:252-63.

[11] Kuzyakov Y, Shevtzova E, Pustovoytov K. 2006. Carbonate re-crystallization in soil revealed byC labeling: Experiment, model and significance for paleo-environmental reconstructions. Geoderma 131:45-58.

[12] Overstreet R, Ruben S, Broyer TC. 1940. The absorption of bicarbonate ion by barley plants as indicated by studies with radioactive carbon. Proceedings of the National Academy of Sciences USA 26:688-95.

[13] Pelkonen P, Vapaavuori EM, Vuorinen H. 1985. HCO uptake through the roots in willow and sunflower and effect of HCO uptake on the productivity of willow cuttings. In: Palz W, Coombs J, Hall DO, editors. Energy from Biomass, 3rd E.C. Conference. London: Elsevier. p 417-21.

[14] Pigati JS, Quade J, Shahanan TM, Haynes CV Jr. 2004. Radiocarbon dating of minute gastropods and new constraints on the timing of late Quaternary spring-discharge deposits in southern Arizona, USA. Palaeogeography, Palaeoclimatology, Palaeoecology 204:33-45.

[15] Pigati JS, Rech JA, Nekola JC. 2010. Radiocarbon dating of small terrestrial gastropod shells in North America. Quaternary Geochronology 5:519-32.

[16] Pustovoytov KE, Riehl S, Mittmann S. 2004. Radiocarbon age of carbonate in fruits of Lithospermum from the early Bronze Age settlement of Hirbet ez-Zeraqōn (Jordan). Vegetation History and Archaeobotany 13:207-12.

[17] Pustovoytov K, Riehl S. 2006. Suitability of biogenic carbonate of Lithospermum fruits forC dating. Quaternary Research 65:508-18.

[18] Pustovoytov K, Riehl S, Hilger HH, Schumacher E. 2010. Oxygen isotopic composition of fruit carbonate in Lithospermeae and its potential for paleoclimate research in the Mediterranean. Global and Planetary Change 71:258-68.

[19] Quade J, Shanying L, Stiner M, Clark AE, Mentzer S. 2014. Radiocarbon dating, mineralogy, and isotopic composition of hackberry endocarps from the Neolithic site of: Asikli Höyük, central Turkey. Tree-Ring Research 70:17-25.

[20] Stolwijk JAJ, Thimann KV. 1957. On the uptake of carbon dioxide and bicarbonate by roots, and its influence on growth. 1. Plant Physiololgy 32:513-20.

[21] Viktor A, Cramer MD. 2003. Variation in root-zone CO concentration modifies isotopic fractionation of carbon and nitrogen in tomato seedlings. New Phytologist 157:45-54.

[22] Viktor A, Cramer MD. 2005. The influence of root assimilated inorganic carbon on nitrogen acquisition/assimilation and carbon partitioning. New Phytologist 165:157-69.

[23] Vuorinen AH, Vapaavuori EM, Lapinjoki S. 1989. Time-course of uptake of dissolved inorganic carbon through willow roots in light and in darkness. Physiol. Plant 77:33-8.

[24] Wang Y, Jahren AH, Amundson R. 1997. Potential forC dating of biogenic carbonate in cackberry (Celtis) endocarps. Quaternary Research 47: 337-43.